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FIELD AND LABORATORY STUDIES OF SOME DEGRADED SASKATCHEWAN SOILS.

Harold Charles Moss.
University of Alberta.

A thesis submitted to the University of Alberta in partial fulfilment of the requirements for the degree of Master of Science.

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FIELD AND LABORATORY STUDIES OF SOME DEGRADED SASKATCHEWAN SOILS.

by H. C. Moss.

In recent years the study of the soil as a natural body, possessing definite characteristics of its own, has received increasing attention from soil workers on this continent. This is largely due to the stimulation afforded by the publication in English of the results of such studies in other countries, notably Russia. The work of the Russian soil scientists has demonstrated the importance of climate in connection with the forces operating in the formation of soil.

Among the major soil groups of the world that have been classified as a result of the above mentioned investigations, that of the soils developed under a cool moist climate may be mentioned. This group is of wide occurrence in Saskatchewan, and it is the purpose of this thesis to make a study of some of the soils in this group, both in the field and in the laboratory.

The soils selected for study belong to the group that have undergone a process of degradation, whereby certain constituents have been removed from the upper layers of the soil body. This will be more fully discussed later on.

In planning this problem it was hoped to gain some information on the following points:-

(I) To determine whether the differences observed in the naturally occurring horizons or layers of the soil, when examined in a fresh vertical cut, could be correlated with differences in chemical composition as measured by analysis.

(II) To see how these soils compared with degraded soils found elsewhere.

(III) To determine what differences exist between degraded soils of different texture and origin, when studied in the same general area.

(IV) To gain some idea of the relative agricultural value of these degraded soils by comparing their chemical and physical properties with those of the fertile park belt soils.

BRIEF REVIEW OF SYSTEMS OF SOIL CLASSIFICATION.

The development of the conception of the soil as a natural body, genetically related to the forces that have brought about its development, has established the study of soils as a distinct branch

of natural science. This conception has been widely adopted by soil investigators only within recent years, and in fact it may be stated that it is not generally realized among workers in other fields even yet; nevertheless the investigations which have been the basis for this viewpoint had their beginnings many years ago. The Russian soil investigators were the pioneers in this field of soil science and it is necessary, therefore, to review the results of their work first.

The work of Dokuchaiev laid the foundation of the Russian system of soil classification. (2/) He took climate as the basis of this system; although he was not the first to realize the value of climate in soil formation, no one up to his time had recognised its importance in soil classification.(5/) His first scheme of classification was published in 1886.

Among other investigators there was a tendency to group soils according to one or the other of two main viewpoints; according to the kinds of crops that could be grown - an agricultural classification; or according to the kinds of rocks and minerals that had weathered on the surface of the earth - a geological classification. (5) As stated by Marbut (17), neither of the above group of investigators was interested in the soil as such and hence no science of the soil could develop until a body of facts concerning it had been accumulated through examination.

The work of Dokuchaiev is, therefore, of great significance in the light of our present day systems of soil classification. He studied the rich black soil of the steppes of Eastern Russia (the Tchernozem) and observed that it was remarkably uniform over a wide area, irrespective of the underlying rock or other parent material from which it was derived. He concluded that this uniformity was a direct result of processes of weathering and processes due to vegetation (10) - both of which are functions of climate. Finally, Dokuchaiev gave a new idea of soil itself "Soil is an independent natural body which must not be mistaken for the surface rocks." (2)

Sibirtsev, one of Dokuchaiev's students, continued the development of the latter's system, and introduced the idea of the zonal system into soil classification. The essential point in this idea is that the great soil groups are distributed in zones or belts over the continental land areas, corresponding in general to the climatic zones. (5) Thus in the equatorial belt lateritic soils are found. On either side of this (north and south) lies an area of desert and dry plains soils. Beyond, on the open plains or steppes are the dark Tchernozem soils; beyond this again the forest and podsol belt; and lastly the tundra soils of the frigid zones. There are, of course, many other types of soils occurring on the earth in which local factors of development have manifested themselves. The zones outlined above contain the soil groups of greatest distribution, and are most typically developed in Eurasia and North America. (5)

Sibirtsev also analysed the climatic forces responsible for soil genesis, and considered moisture the most important factor. He noticed the difference in moisture distribution in Russia as compared with North America. In the former case the moisture decreases from north-west to south-east; in the latter from east to west.(5) Another point noted by this investigator was that temperature is also an important factor, as illustrated by the geographical distribution of the Tchernozem belt. This belt, although uniform, does not receive uniform rainfall; as the zone extends eastward toward the interior, the rainfall decreases. This is compensated by the fact that the zone continually runs further north, and the lower rainfall is offset by a cooler climate and consequent lower evaporation. Hence the general conditions of moisture are the same over the whole zone. (5)

It is interesting to note that of American investigators Hilgard approached more nearly the views of the Dokuchaiev - Sibirtsev school of classification. He also considered moisture the essential factor in soil development, and on that basis grouped soils into arid and humid soils. He did not, however, correlate the factors of soil development with a systematic classification of soils. Furthermore he emphasized the parent rock as the starting point in the development of the soil characters and hence may be said to belong to the geological school of soil science. (10)

Following Dokuchaiev and Sibirtsev came many other investigators, in Russia and elsewhere. Among the Russians Glinka claims attention, not only for his work in carrying the climatic basis

of soil classification still further but largely on account of his thorough treatment of the subject in his book "The Great Soil Groups of the World and Their Development." (5) English speaking investigators are indebted to Dr. Marbut's translation of this work from the German text for the first comprehensive review of the Russian viewpoint in regard to soil classification.

Glinka's own scheme of classification was another in which moisture was the important climatic factor. Thus he designates the soil zones as soils "of optimum moisture", (5) "soils of average moisture", etc. He also realized that some soils do not fit into a classification based on climate and he placed these in a group apart - calling them endodynamorphic soils - those in which internal properties (as parent material) have prevented the development of the normal climatic soil type.

Ramman, (16) a German, was another investigator who developed a system of soil classification based on climate. He was influenced also by the Russian school, but in some ways his classification is similar to Hilgard's (10) in that he designates soil groups as Humid and Arid.

Other systems of soil classification developed in Europe in recent years are those of Zakharov (2), Afanasiev, Tiurin, Gedroiz, Nuestruev (2), and others. Nuestruev (2) based his classification on the processes (in the chemical sense) by which the soil was developed. He also stated that the characteristics of the profile, i.e. a vertical cut exposing the various naturally occurring soil layers or horizons

"are the outward manifestation of the process of transportation of substances". (2) Another important statement is that "Morphological observations confirmed by physico-chemical investigations help to determine the type of soil foundation." (2) The views of Gedroiz are interesting in view of the important studies being made at the present time in the field of base exchange in soils. Gedroiz classifies soils on the basis of the cations found in the absorptive soil complex. (2) Thus the Tchernozem is a soil saturated with calcium and magnesium; whereas the podsol is a soil containing less of these cations and in their place some exchangeable hydrogen.

Another modern classification based on the chemical point of view is that of Aarnio, (1) who states that different types of soil are characterized by their different products of decomposition. His classification is based on the characteristic substances found in different soils. Thus the Tchernozem is called a humus and alkaline earth soil, while the podsol is a sesquioxide soil.

On this continent the investigations of Marbut are outstanding in recent times. His classification (11) is an attempt to define the great soil groups in terms of inherent differences in the soil profile. His first division is simply into those soils containing accumulated calcium carbonate (called pedocal soils), and those which do not contain lime (called pedalfers.). A line running roughly from the north-western corner of Minnesota to a point in Texas separates these groups into an east and west division. West of this line is the area of pedocalic soils; east of it lie the pedalferic soils.

The division corresponds in the main to differences in soil moisture. The pedocals are, in general, aridic soils; the pedalfers are humid soils. (24) The further classification of each of these groups is based on differences in the genetic development of the soils, as shown by differences in the colour and other characteristics of the mature profile.

In Canada the only comprehensive attempts at soil classification from the climatic zonal viewpoint are those of Wyatt and Newton (25&26) in Alberta, and of Joel (7&8) in Saskatchewan. In both provinces soil belts or zones have been differentiated on the basis of differences in the soil profile. These differences are considered as being due to differences in climatical and vegetative features. Thus from south to north there are in succession brown, dark-brown, black, and grey soils, corresponding to successive increases in soil moisture; and also passing from short grass, tall grass, "park" vegetation to wooded or "bush" conditions.

To sum up the position of soil classification it may be stated that since the day of Dokuchaiev and Sibirtsev, the concept of soil as a natural body, and the position of the climate as the fundamental soil-forming agency have been more firmly established by each succeeding school of soil investigators. This is true in spite of the fact that differences of opinion exist as to the relative importance of this or that factor. When we consider the great number of investigators engaged in soil classification, and the great variations in climate, vegetation, and parent rock encountered by them

it is remarkable that the modern concepts of soil and soil development are so widely accepted. Such a state of affairs may reasonably be considered as offering confirmation of the essential soundness of the above views.

SOIL MORPHOLOGY.

In connection with soil classification it may be noted that the soil profile has received increasing attention during late years. This is but natural when it is remembered that soils are differentiated largely on the basis of differences within the profile.

The study of the morphology of the soil is essentially the study of the characteristic features of the profile - that is the appearance, form, colour, and other qualities of the separate horizons or layers as observed in a fresh vertical cut exposed from the surface downwards. (29)

The development of this study was naturally dependent upon the development of soil science as an independent science,(10); it is natural, therefore, that the Russians were the pioneers in this field also. (10)

It is not necessary to review the rise of this branch of soil science in detail. To do so would be to repeat essentially what has already been covered in the section on soil classification. The name of Zakharov must be mentioned, however, as being one of the most prominent soil morphologists of Russia today. (10)

Zakharov has a very comprehensive review of the Russian work in soil morphology in his paper of 1927. (29) In this he outlines in brief form the main morphological features of the soil as follows:

I. Colour of soils.

II. Structure of soils - the fragments into which the soil breaks up.

III. Constitution of soils, relating to porosity and compactness of soil.

IV. Thickness of the whole soil and of horizons.

V. New growths and intrusions - accumulations in soil cavities of substances resulting from soil-making process.

VI. The coarse part of the soil and organic remains. In general the remains of substances not spared by weathering.

VII. Profile characteristics of soils (their general aspect).

This last factor, relating to profile characteristics, may be said to embody the essential features of the preceding factors. It is through the study of the general aspects of the profile that soils are classified in the field. Out of this study has arisen the concept of the zonal profile - a profile that may be said to be typical of the climatical zone in which the soil has developed. Thus over the area covered by one of the main climatic soil zones, profiles have developed having a characteristic morphology, irrespective of the parent materials from which the soils have been derived. (10)

Within such a soil profile several main horizons have been designated, (29) - as follows:

Upper horizons of humus accumulation, usually referred to by letters A_0 and A_1.

Horizons of eluviation, i.e. those from which substances have been leached through weathering, (A_2, etc.).

Horizons of illuviation - those which have received substances leached out from the A horizons. (Horizons B_1, B_2, etc.)

Horizons of almost unweathered material considered as being the parent material from which the soil above has developed. (Horizons C_1, C_2, etc.)

The above system, in some cases modified by certain investigators, is in general use at the present time; thus in Alberta and Saskatchewan it is customary to designate the horizon of lime carbonate accumulation as B_2.

DEGRADED SOILS OF TEMPERATE REGIONS. (Podsolic Soils.)

Among the great climatical soil groups referred to in the discussion on classification, the zone of "Podsol" soils was mentioned. These soils are found in the temperate regions, (both north and south of the equator), under climatical conditions that may be classed as cool-moist. Such conditions favour the development of wooded vegetation. As a result of further changes induced by the above, the soil profile acquires a distinctive appearance and composition.

The combined effects of a cool moist climate and wooded vegetation create a more or less permanently moist profile, (24) in which the water movement is predominatingly downward. Furthermore, these conditions do not favour the accumulation of organic matter. (5) The "forest litter" of dead leaves and other plant remains accumulate on the surface largely as raw humus in a layer distinct from the soil proper. Some organic matter is found in horizons A_1 and B_1, but in much smaller amounts than is present in the A horizons of the black (Tchernozem) type of soils. The continued action of the water percolating through the raw humus into the mineral soil is thought to liberate intermediate products of decomposition, (5) of which organic acids are an example. The presence of carbon dioxide in the water may also give a slightly acid solution.

There is, therefore, a downward movement of water in a more or less acidic condition. This brings about a process of degradation due to the combined effect of chemical and physical leaching. As a result there is a loss of certain chemical substances from the upper horizons A_1 and A_2 and an accumulation of substances in the B horizons. (5)

The materials removed from the A horizons are the sesquioxides of iron and alumina, alkalies and alkaline earths, silica, organic matter and nitrogen. Some phosphorus may be leached out also, although generally to a slight extent only. As a result the A horizons become coarser in texture, with an increase in silica content. The A_2 horizon becomes ash-like in colour hence the name "podsol". (5) From the Russian word for "ashes".

The B horizons accumulate mainly the sesquioxides, and, to a lesser extent, organic matter and bases. The soluble substances such as salts are largely washed out altogether. These horizons tend to become heavier in texture than the A layers and may even become highly impervious.

The net result of this degrading process is to impoverish the upper layers of soil in regard to chemical elements and organic matter and also in regard to the finer clay-like particles. The podsolic soil, in chemical and physical properties, tends to develop into a relatively poor soil from the standpoint of agriculture. (24)

With regard to the actual process by which the podsolising effect is produced, especially in connection with the question of how much of the leached material is moved mechanically and of how much is moved chemically, no full explanation has so far been given. (11)

It may be assumed that it is generally accepted that the process involves the conditions mentioned above, - namely downward movement of water and more or less acidic conditions, under a relatively cool temperature. Another important point that is stressed by several investigators is that the movement of sesquioxides and organic matter from the A horizons cannot take place until the lime carbonate has been removed from these layers. (11, 17, 23.)

The movement of lime in an acid solution would be relatively easily effected, due to the formation of soluble calcium bicarbonate $Ca(HCO_3)$. When this has occurred the soil tends to become deflocculated and dispersed. It is, therefore, in a condition to be removed, -

probably by both the mechanical effect of percolating water and by the chemical effect of solution or colloidal combination. (24)

It is only in recent years that any laboratory work has been undertaken in connection with this question of how the podsolic forces operate. According to Marbut (11) very little literature is available; a review of the research carried on in Europe is given by him in his Lectures to the Graduate School, Washington, 1928. These cannot be reviewed in detail, but the main conclusions according to Marbut's discussion, that may be drawn from the results, are summarized as follows:-

According to Tamm the leaching process in the A_2 horizon is one of solution, not decomposition. Decomposition may occur as in ordinary rock weathering, but this is not specifically a part of podsolic degradation.

As a result of this solution process, the alkalies, alkaline earths, aluminum, iron and silica are removed from the A_2 horizon. No weathered products are found in the leached layer.

The results of experiments by many workers has led to a belief that the organic matter and the aluminum, iron and silica move largely in the form of a colloidal sol. The removal of lime is thought to favour the "sol" state. According to Aarnio (1) silicic acid, sesquioxides and compounds of silica and aluminum pass into the colloidal state by hydrolysis.

The precipitation of these substances in the B horizons is thought to occur through the flocculation produced by the presence

of sufficient concentrations of oppositely charged colloids, or electrolytes. The work of Aarnio has shown that colloidal iron or aluminum may be precipitated by colloidal organic matter, when these are present in certain ratios. The concentration necessary to cause flocculation and subsequent precipitation in the B_1 layers may be due to the increased concentration of the soil water solution at these lower depths.

A certain amount of the finer soil material is thought to be moved mechanically by percolating water from the A to the B horizons.

The question of podsolic degradation, in regard to the causes and processes by which it is brought about, is thus seen to be one of great complexity. At the present time it may be stated that the appearance of such degradation can be observed in the field; and the results of the leaching and deposition may be measured by analysis in the laboratory.

Soils which have suffered podsolic weathering are of wide occurrence, wherever climatic and geographic conditions favour their development. The occurrence of these soils has been reported from Canada; (7,8,9,14,25,26); the United States, (4,11,13,22,25); Russia, (2,5); and other parts of Europe, (15,16,19,23);and also from South America, (11), and Australia, (18).

MAIN SOIL BELTS OF SASKATCHEWAN.

In order to make a proper study of the degraded wooded soils

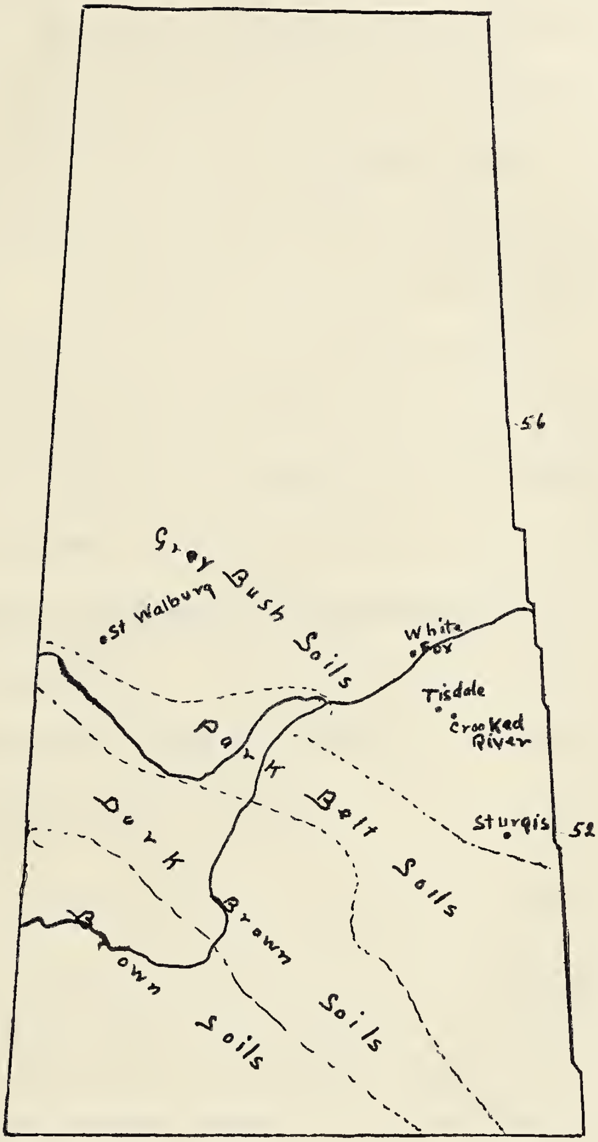
of Saskatchewan, it will be necessary to consider briefly the character and distribution of the main soil groups found in the province.

The soils of Saskatchewan, (7,8,9) have been placed in several main belts or zones, based on differences in the soil profile. These differences are attributed chiefly to variations in climatical conditions under which the profiles have developed.

A rough outline of these belts is shown in the accompanying diagram. (Fig. 1 - p.17) The colour terms refer to the characteristic colour of the surface horizons. The south-west portion of the province has a drier climate than the north and east sections, and this is shown by the appearance of the soil and the character of the vegetation. Thus in the zone of brown soils, the upper horizons are brown in color, the vegetation is typically one of grasses and other plant associations of plains areas. The dark brown belt has a heavier grass stand and odd clumps of trees, while the soil shows a higher accumulation of organic matter, giving it a slightly darker colour. The park belt has black or nearly black soils, with a high organic matter content; the vegetation is largely poplar and willow trees, with tall grasses in the open areas. This is typical also of the grey soil zone - the only difference being that wooded conditions and high soil moisture have existed long enough to start degradation in the soil profile; as a result the soil has the characteristic "podsolic" type of profile and the leached upper layers give the soil the distinctive grey colour. Furthermore, coniferous trees and peat vegetation become more common.

Fig I

Saskatchewan



Map Showing Location of Profiles and Main Soil Belts, (approximate)

As stated above this classification is based on broad differences in climatical conditions, and, therefore, the boundaries between the different belts are not to be considered as making a sharp division. Such factors as the geolical origin of the soil, affecting texture and topographic position ~~is~~ are important locally in modifying the soil profile. Nevertheless, the main soil groups express the outstanding characters of the soil over wide areas.

The variation in climatic forces that gives us a shallow brown soil and short grass vegetation in the south-west, and a heavy tree growth and deeper soil profile in the north, is the result of two factors; - one of difference in precipitation, and another of difference in rate of evaporation. It is surprising to note that the actual variation in rainfall between a point in the brown belt and one in the park belt is only about one inch.

Table I - Rainfall and Humidity Records in Different Soil Zones.

Station (Records from April to Sept.	Rainfall	Humidity
Swift Current (brown plains)	14.83 inches	69%
Prince Albert (park and grey soil)	15.81 "	79%

Adopted from data given in Saskatchewan Soil Survey - Report No. 7.

The difference is much greater, however, in regard to humidity, and it may be inferred that the more rapid evaporation of moisture occurring on the open plains, as compared with the wooded areas, is a big factor

in the development of such diverse soil profiles and vegetation. This lower rate of evaporation occurring in the more northerly areas is in turn largely controlled by a relatively lower average temperature. The Melfort district, just west of Tisdale, has a mean annual temperature of 32.3^{O}F., which is about 2^{O}F. below the average for the province. The amount of precipitation received by the soil in the park belt would not support trees nor be sufficient for the development of degraded soils, in any region where the average temperature is higher than that prevailing in the north temperate zone.

FIELD STUDIES.

The degraded soils selected for this problem belong to the types encountered along the northern edge of present settlement in Saskatchewan. Soil survey operations during the summers of 1929 and 1930 afforded an opportunity for studying these soils in the field.

Soils showing a greater depth of leaching may occur further north; as yet practically no information is available on this point. During the summer of 1929 some degraded soils were studied within the area of the National Park, about seventy miles north of Prince Albert. These soils showed evidence of greater leaching than is common to the soils of wooded areas surveyed further south. According to Dr. Wyatt the degraded soils observed north of Prince Albert were more comparable to the wooded soils of Alberta.

The profiles discussed in the following pages are not intended, therefore, to represent those soils that have suffered the greatest

amount of degradation; they are rather indicative of the main types of wooded soil upon which settlement has taken place, and upon which it is proceeding at the present time.

During the survey of these areas, the topography, vegetation, soils and other features were mapped. The soil profiles studied were selected on the basis of the information secured by the mapping.

A great many profile examinations were made; those selected for further study were considered to be representative of the local environment in which they were found.

The method of studying the profile consisted of exposing a fresh vertical cut, in which each horizon could be differentiated. The profile was dug in a level well-drained location. The depth of each horizon was noted, together with the colour, structure, and any-other features that might be characteristic. Individual samples were taken from each horizon.

It will be noted in the following descriptions that no mention is made of the C horizon; the reason being that in these highly calcareous soils no sharp division seemed to occur when once the horizon of lime accumulation was reached. Most of the wooded soils are in a wet condition at this depth, and, therefore, such differences as those of colour are likely to be masked. Furthermore, if the B_2 layer can be properly separated from that below, it is doubtful if the lower horizon can be considered as practically unweathered parent material.

Evidences of weathering are found for a considerable depth below that at which the lime accumulation is first encountered. However, the sampling of the profile from the surface to the B_2 horizon will mark out the zone in which chemical and physical weathering has been most active.

In the following pages the information derived from the field studies of five profiles is given in Table II, followed by notes taken at the time of sampling in reference to topography, vegetation and other important local factors.

Table II - Profile Descriptions of Saskatchewan Degraded Soils.

WHITE FOX PROFILE (Very fine sandy) Alluvial.

Depth	Texture	Colour	Structure, etc.
0"-2"	Organic layer.	Black.	Apparently peat originally - burnt off, now developing grassy cover.
2"-4"	Very fine sandy loam friable.	Very dark grey.	Thick platy, slightly leached.
4"-8"	Very fine sand.	Dark grey with brownish tinges.	Structureless, very little "stick", - leached layer.
8"-10"	Loam (silty).	Brownish-grey.	Granular- streaks of red iron oxide occur.
10"-16"	Heavier loam with some sand.	Rusty-grey.	Somewhat platy, spots of red iron oxide.
16"-21"	Very fine sand.	Brownish yellow.	Very little structure or "stick".
21"-25"	Heavy loam.	Blue-grey with streaks of yellow.	Coarse granular, heavier textured.
25"-46"	Very fine sandy loam.	Light yellowish-grey.	Granular, some "stick". Faint effervescence with HCl.
46"-56"	Very fine sandy loam some silt.	Light grey with small white lime concretions.	No structure. Considerable effervescence.

Table II - cont.

TISDALE PROFILE; SILTY CLAY LOAM (Lacustrine.)

Depth.	Texture	Colour	Structure, etc.
0"-2"	Organic.	Black.	Dead plant remains, undecomposed. A_0 Horizon.
2"-7"	Heavy silty clay loam.	Dark grey.	Coarse granular structure. Mineral soil high in organic matter. Stone free. Horizon A_1, slightly leached.
7"-11"	Heavy loam (silty).	Grey, with slight brown shade.	Thick plates (schistose), breaking up into small granules, under pressure becomes powdery. Leached A_2 horizon.
11"-24"	Clay (silty).	Dark grey, brownish.	Somewhat columnar, breaking into coarse angular fragments. Very sticky when wet. At the bottom grades into horizon below with no sharp change of colour or appearance. Horizon B_1.
24" plus.	Heavy silty clay loam.	Greyish-white streaked with lime.	No structure evident (very wet when taken). Sticky, horizon of lime carbonate accumulation (B_2). Considerable effervescence.

Table II - cont.

CROOKED RIVER (Glacial loam)

Depth	Texture	Colour	Structure, etc.
0"-1"	Highly organic.	Dark greyish black.	Friable, mixture of mineral soil and organic matter after surface fire. (Horizons A_0 and A_1).
1"-8"	Gritty loam.	Ashy-grey with few reddish spots.	Slight evidence of platy structure, but easily crushed to powder. Leached A_2 horizon.
8"-14"	Clay loam.	Coffee brown.	Prismatic structure, with sharply defined edges, crushing into coarse tough granules. Small pores occur on prisms. Numerous granitic and limestone chips, disintegrating. Very faint effervescence; upper B_1 horizon.
14"-18"	Clay loam.	Coffee brown to yellow-brown.	Prismatic as above. Pores more numerous. Very stony layer. Considerable effervescence. Lower B_1 horizon.
18"-55"	Heavy clay loam.	Grey to dark grey.	Coarse granular, many particles of disintegrating rock. Vigorous effervescence, horizon of lime accumulation (B_2).

Table II - cont.

STURGIS PROFILE. (Gently rolling glacial loam.)

Depth	Texture	Colour	Structure, etc.
0"-$\frac{1}{2}$"	Organic.	Black.	Plant remains. A_0 horizon.
$\frac{1}{2}$" -4"	Loam (coarse gritty).	Grey.	Slight evidence of platy structure, easily crushed to powder. Leached. Wet profile - difficult to separate A_1 and A_2.
4"-8"	As above.	Ashy-grey.	Similar to above, but no evidence of organic matter.
8"-18"	Heavy loam to clay loam (very gritty).	Grey-brown.	Somewhat columnar, small stones and gritty particles of disintegrating rock present. Horizon of accumulation B_1.
18"-22"	Clay loam. Stony.	Dark-brown.	Nutty to granular structure, more stony than above layer. Faint effervescence. Lower B_1 horizon.
22" plus.	Loam. Gritty stony.	Light grey.	Fine granular horizon of lime carbonate accumulation (B_2). Small limestone fragments present among stony particles. Strong effervescence.

Table II - cont.

ST. WALBURG PROFILE. (Glacial loam.)

Depth	Texture	Colour	Structure, etc.
0"-2"	Organic.	Black.	Dead plant remains. A_0 horizon.
2"-2½"	Fine sandy loam.	Dark greyish.	No structure, mineral soil high in organic matter. Horizon A_1.
2½"-7½"	Light loam.	Ashy-grey.	Powdery structureless leached layer, A_2.
7½"-13"	Clay loam.	Dark greyish-brown.	Coarse granular, horizon of accumulation. (B_1).
13"-36"	Clay loam - Heavy clay loam.	Dark greyish.	Somewhat columnar, breaking to coarse granules, dark coatings occur on soil particles. Weathered stones and pebbles, basic stones weathering to clay. Horizon of accumulation, B_1.
36"plus.	Clay loam.	Dark grey to grey (mottled).	Granular. Some root channels appear in this layer carrying mycelium like threads. Horizon of lime accumulation, B_2. Considerable effervescence.

White Fox Profile - taken in Twp. 51-15-W2nd. near White Fox. Location about two miles west of the Saskatchewan River. This soil is chiefly very fine sand, except in lower horizons, and is stone free.

Surrounding area a level plain dotted with odd clumps of spruce trees. The surface was apparently covered with peat in the past, but has since been burnt over. In a clump of spruce trees about twenty yards away, where the fire had not penetrated, peat up to 8"-10" was found. The open area is now supporting small scrubby willows and a thin grass vegetation.

A little cultivation was observed near by, consisting of a few acres of a poor crop of wheat. Most of the land of this type is unsettled in this vicinity.

This profile is one that has developed, apparently, from alluvial material carried by the river; the older topographic maps show this area as a swamp or muskeg; the appearance of some of the lower horizons suggests that there was a shallow water table at some time under this soil. The drainage has improved, however, and leaching has been in operation long enough to completely remove the lime carbonate to a depth of twenty inches; very little is left above four feet.

In common with most sandy profiles, the appearances of podsolic leaching in this soil are not as intense as those observed in heavier podsolic soils.

Tisdale Profile - taken in Twp. 47-14-W2nd., north of Tisdale. Surface soil is of smooth heavy, stone-free type (lacustrine). Mapped as heavy silty clay loam, and is similar to the soil of the Melfort area about 25 miles to the west. The latter soil does not show any degradation, however.

The surrounding area in the case of this profile is gently undulating and fairly well cultivated. A heavy stand of poplar up to 12" diameter occurs on uncleared land, indicating that the original vegetation was largely timber. On burnt over areas heavy growths of young poplars and willows are developing.

This profile is interesting in showing that podsolic degradation may occur in the heavier soils. This area is approaching the edge of the heavy lacustrine soils, and has probably been under wooded vegetation longer than the black Melfort soils.

Crooked River Profile - taken in Twp. 45-12-W2nd., a few miles east of Crooked River. Soil is of morainic loam type, carrying much grit and small stones. Glacial boulders are found in vicinity.

Surrounding area is gently undulating, consisting of alternating better drained upland covered with poplar trees, and low poorly drained spots supporting spruce and willows.

Very little settlement in vicinity. Cultivated field near by has characteristic ashy appearance, typical of podsolic soils. Cost of clearing bush and stones, and the presence of low wet areas are drawbacks to settlement.

Sturgis Profile - taken in Twp.36-4-W2nd., near Sturgis. Morainic loam type - coarse and stony throughout profile.

Topography undulating to gently rolling, moderate amounts of stones and boulders present. Heavy poplar bush in vicinity. The leached horizons of from 7"-8" thick are coarse and gritty.

Very little cultivation or settlement in vicinity. Presence of stones and trees, and coarse nature of the soil will affect settlement.

St. Walburg Profile - taken in Twp.55- -W2nd. north east of St. Walburg. Morainic loam type.

Topography gently undulating - well drained areas interspersed with low wet areas of muskeg; the latter often occur in conjunction with low sandy jackpine ridges.

The better drained land has a heavy poplar growth, with trees up to 12" diameter. Sandy patches support jackpine. Some spruce in wet areas, a dense growth of alder, saskatoon berry and other shrubs common to moist localities are found also. Practically no settlement or cultivation. This area would require heavy clearing before settlement could develop. The better drained land is cut up by the low wet areas.

This profile indicates considerable leaching; the ashy A_2 horizon is quite striking on account of the very thin A_1 horizon; the B_1 horizons are very deep, almost 2½ feet in thickness, and the lime is not encountered above three feet from the surface.

These profile descriptions indicate that all the soils selected for study belong to the podsolic group. The profiles are

distinguished by the layer of undecomposed organic matter on the surface, except where fire has destroyed it; by the dark grey A_1 horizon, which may be very thin, and in other cases of a platy structure; by the leached ashy coloured A_2 layer - generally structureless or easily crushed to powder; by the heavier B_1 layer, sometimes separated into two parts and generally dark in colour and sometimes columnar in structure; and finally by the highly calcareous B_2 layer or zone of lime carbonate accumulation, lighter in colour than the B_1 horizon.

DISCUSSION OF PROFILE DATA FROM OTHER SOURCES.

In contrast to the above soils the park belt profile has a deeper A_1 horizon and has no leached A_2 layer. There is no distinctive horizon of accumulation, as compared with the heavy dark brown B_1 layer of the degraded soils.

The degraded soils found in Alberta and classified as wooded soils (26) have a deeper profile than is usual in the soils studied above; these wooded soils are leached of their lime carbonate to a depth of from four to six feet, the A_2 leached horizon may be a foot or more in thickness and the A_1 is generally thin - about one or two inches. These Alberta soils have, therefore, suffered more leaching than the Saskatchewan soils reported above.

Another group of degraded soils of Alberta is that of the incipient podsolic wooded soils. These soils have a lime carbonate layer three to four feet below the surface, the A_2 horizon is generally four to eight inches thick and the A_1 may be absent. It may be seen

that the St. Walburg profile bears a general resemblance to this group.

Descriptions of podsolic soil profiles are reported from other parts of this continent, notably Quebec, (14), the north central states, (4), Michigan, (22), and New Jersey, (10). Compared with our degraded soils, these descriptions indicate a greater degree of leaching, and, therefore, the profiles are usually much deeper. No lime carbonate is reported in any horizon except in the C layer designated as parent material.

The profiles of some Russian podsol soils, reported by Glinka appear to have a fairly shallow A_2 layer, the deepest one mentioned being ten inches for a sandy podsol. No mention is made of a lime carbonate layer. The degraded Tchernozem soils reported by the same author do show a layer of high calcium carbonate content; these soils are considered to be former steppe soils that have become degraded as a result of the invasion of wooded vegetation; the lime carbonate present is looked upon, therefore, as a part of the old steppe profile. In contrast to our degraded soils it is interesting to note that the A_2 of the degraded Tchernozems is reported as having a pronounced "nutty" structure, and is about twenty inches in thickness.

Some very interesting profiles from Latvia are reported by Wityn (23). These soils have well developed podsolic profiles, and are derived from highly calcareous parent material. Some of the profiles that still contain lime seem to correspond to our glacial podsolic soils.

Descriptions of podsolic profiles are reported also from other parts of the world; these descriptions vary with respect to texture, extent of leaching and other factors; they are all, however, distinquished from other soil profiles by the light coloured leached layer, the heavier dark B_1 horizon, and usually, the A_0 layer of undecomposed organic matter.

From the above descriptions it may be seen that the degraded Saskatchewan soils, selected for this study, belong to the group of soils formed under conditions of podsolic weathering; despite the high lime carbonate content of the lower horizons, the leaching process has developed the typical podsolic horizons in the upper part of the profile. The presence of this accumulated lime may be explained on the basis of our lower rainfall, as compared with most of the podsol regions; also by the possibility that our soils have developed on more highly calcareous parent material; and also by the assumption that these are comparatively young soils.

In any event it is reasonable to suppose that if the profile and the climatic conditions were left undisturbed, it would be only a question of time before the podsolic process developed a more severely leached soil.

LABORATORY STUDIES.

As stated above the process of podsolic degradation involves the removal of various substances, by leaching, from the upper to the lower horizons of the profile.

It was further stated that the effect of this leaching process may be observed in the field, and the results of field studies on some Saskatchewan soils were also given.

In order to find out the extent and nature of the degradation, representative samples from each horizon of five selected profiles were analysed in the laboratory. The following constituents were determined;- nitrogen, phosphorus, silica, total oxides, (Fe_2O_3, Al_2O_3, TiO_2), calcium, and calcium carbonate. In addition determinations were made of hygroscopic moisture, loss on ignition and pH value.

Total oxides, calcium, and lime carbonate were determined as being the substances whose removal from one horizon to another is the most outstanding characteristic of the chemical profile of podsolic soils. Silica was determined because in such soils it reaches a higher content in the leached A_2 horizon than it does in the B horizons, occurring in the reverse order as compared with total oxides. The loss on ignition was determined as giving at least a partial measurement of the organic matter content and distribution. Nitrogen and phosphorus were determined largely on account of their importance in soil fertility, although both may follow the distribution of total oxides, to a lesser extent. Percentage of hygroscopic moisture was also determined.

METHODS OF ANALYSIS.

The following is a brief outline of the methods used in making the above determinations:-

Hygroscopic moisture - Three to four gram samples were heated

to 105° - 107°C. for twelve hours, and the loss in weight reported as percentage of air dried soil. All samples in the subsequent analyses were reported on a moisture free basis.

Phosphorus - determined by a modification of the Fiske-Sabarrow method, as developed by T. Mather, (12), and used in the Soils Department at Alberta.

Nitrogen - determined by the Gunning Hibbard method.

Silica - determined gravimetrically after a sodium carbonate fusion, carried out according to the method given by Lehner and Truog. (6)

Ferric and aluminum oxides - determined gravimetrically from filtrate of silica separation by precipitation with ammonia, according to Treadwell and Hall. (21) The results included the content of titanium, and were reported as total oxides.

Calcium - determined in filtrate from ammonia separation, as calcium oxalate, according to Hibbard. (6)

Loss on ignition - determined by heating soil in electric muffle at 550° - 600°C.

Inorganic carbon - determined by means of the Parr carbon apparatus, and reported as calcium carbonate. It was realized that this would not be fully accurate if magnesium carbonate were present; since, however, the horizons carrying any quantity of inorganic carbon were relatively high in calcium, it was assumed that nearly all the carbon was present as calcium carbonate.

pH value - determined by means of the quinhydrone electrode, according to Biilman and Tovborg-Jensen. (3)

The following Table (III) gives the results of the analyses of the five profiles, carried out by the methods outlined above.

Table III - Chemical analyses of Saskatchewan Degraded Soils.

WHITE FOX PROFILE (sandy).

Horizon	Depth	%H_2O	Loss on Ignition	N.	P.	SiO_2	Total Oxides	Ca	$CaCO_3$	pH
A_o	0"-2"	4.28	20.37	.827	.081	60.68	9.29	1.84	--	7.6
A_1	2"-4"	1.00	2.82	.074	.029	80.45	10.52	.84	--	7.5
A_2	4"-8"	1.00	2.52	.060	.027	80.52	10.10	.92	--	7.4
B_1	8"-10"	2.12	2.49	.099	.078	76.47	14.04	.85	--	7.2
	10"-16"	2.38	2.74	.049	.053	76.16	15.42	.88	--	7.1
	16"-21"	1.51	1.79	.031	.050	79.55	13.41	.97	--	7.1
	21"-25"	2.50	2.80	.043	.047	74.85	15.51	1.01	~~00~~	7.4
	25"-46"	1.50	2.80	.034	.053	78.05	14.58	1.12	.46	7.4
B_2	46"-56"	1.30	2.10	.025	.046	71.01	11.60	3.84	9.33	8.2

TISDALE (Smooth lacustrine).

Horizon	Depth	%H_2O	Loss on Ignition	N.	P.	SiO_2	Total Oxides	Ca	$CaCO_3$	pH
A_o	0"-2"	6.50	30.11	1.060	.106	50.13	13.56	1.48	--	6.9
A_1	2"-7"	6.30	6.42	.254	.052	66.74	19.34	1.04	--	6.6
A_2	7"-11"	2.85	3.00	.115	.026	76.54	13.81	.93	--	6.9
B_1	11"-24"	4.78	5.32	.084	.029	64.50	24.00	.76	00.00	7.5
B_2	24"plus	5.10	5.21	.077	.055	58.01	22.88	2.98	7.13	8.1

Table III - cont.

CROOKED RIVER (Glacial).

Horizon	Depth	%H_2O	Loss on Ignition	N.	P.	SiO_2	Total Oxides	Ca	$CaCO_3$	pH
A_1	0"-1"	2.00	8.80	.341	.100	72.4	9.71	1.76	--	7.5
A_2	1"-8"	1.39	1.98	.067	.050	80.3	12.91	.95	00	6.8
(B_1	8"-14"	3.54	4.56	.071	.050	67.82	15.91	1.24	..82	7.7
(B_1	14"-18"	2.78	4.19	.069	.033	61.22	15.43	4.03	11.45	8.0
B_2	18"-55"	2.00	3.53	.040	.041	54.94	12.63	7.63	24.9	8.1

STURGIS (Glacial).

Horizon	Depth	%H_2O	Loss on Ignition	N.	P.	SiO_2	Total Oxides	Ca	$CaCO_3$	pH
A_0	0"-$\frac{1}{2}$"	7.77	29.5	1.07	.097	53.05	8.44	2.30	--	7.1
A_1	$\frac{1}{2}$"-4"	0.70	2.82	.081	.033	80.20	10.93	1.16	--	6.9
A_2	4"-8"	0.72	1.70	.046	.021	79.04	12.25	.84	--	7.0
(B_1	8"-18"	2.34	2.60	.062	.026	75.60	15.74	1.10	00	6.7
(B_1	18"-22"	3.10	2.16	.053	.044	70.50	16.88	1.40	.46	7.0
B_2	22"plus	0.50	1.34	.020	.042	62.25	14.25	4.96	16.43	8.1

Table III - cont.

ST. WALBURG. (Glacial).

Horizon	Depth	$\%H_2O$	Loss on Ignition	N.	P.	SiO_2	Total Oxides	Ca	$CaCO_3$	pH
A_o	0"-2"	5.34	32.80	1.55	.114	54.23	6.00	2.19	--	7.3
A_1	2"-2½"	1.22	4.90	.186	.031	82.82	8.31	.91	--	7.3
A_2	2½"-7½"	.62	1.21	.030	.012	84.91	8.64	.70	--	6.9
(B_1	7½"-13"	1.90	3.02	.050	.018	79.06	14.46	.75	--	6.4
(B_1	13"-36"	1.85	4.66	.037	.023	79.85	14.34	.75	00	6.5
B_2	36"plus	1.24	6.57	.024	.038	76.68	11.13	3.09	8.75	7.8

The analytical results reported above indicate that these soils have been subjected to the degrading processes associated with podsolic leaching; that is, in all cases the B_1 layers are higher in total oxides than the leached A_2 layers. The silica on the other hand is always higher in the A_2 than in the B_1. The calcium content is higher in the surface horizons than in the A_2 layer, but in all cases reaches a maximum at some point well within the B horizons. The accumulation of lime carbonate occurs in these same horizons as shown by the figures for $CaCO_3$. No lime was found in any of the A_2 layers.

The nitrogen and phosphorus are both found in greatest amount in those horizons relatively high in organic matter, (A_0 and A_1); and slight increases over the A_2 content are to be observed in the top B_1 layer. One or two exceptions to the above statements occur, and these will be discussed later.

The loss on ignition and moisture content are lower in the A_2 than in the B_1 horizons. The highest figures for both occur in the A_0 layers.

The pH values are in general indicative of the fact that these soils are not very acidic. In three profiles the lowest pH values occur in the B_1 layers rather than in the leached A_2 horizons.

The White Fox profile is characterized by a lower lime carbonate horizon than is found in the other profiles. This is in accord with data from other places, and may be taken as indicating that the light textured soils allow percolating water to pass through them more easily than do the heavier soils. Thus the lime carbonate

[illegible]

would be removed more readily to deeper depths in the case of sandy soils. Another noticeable feature of this profile is the presence of five horizons between the A_2 and the horizon of lime accumulation. (B_2) This soil is considered to be of alluvial origin and it is very probable that the present profile has developed on material of varying texture. The figures for silica and total oxides suggest that there is a succession of light and heavy layers below the A_2 horizons. These figures agree with the textural classification found in the field. Wherever a horizon of relatively light texture is found the content of silica is relatively high and that of the total oxides correspondingly lower.

The content of nitrogen and phosphorus is curiously high in the upper B_1 horizon of this profile. This is all the more unaccountable in view of the fact that the loss on ignition does not indicate any exceptional accumulation of organic matter in this horizon. The content of these elements is noticeably lower in the A_2 horizon. A gradual decrease with increasing depth is also indicated for nitrogen and phosphorus, with the exception of the horizon just above the B_2; in this the phosphorus content rises slightly.

The pH values for this profile are the highest throughout of all the samples studied. No pH below 7.1 is recorded. The A_0 and A_1 layers give the highest figures, with the exception of the value for the B_2 horizon.

The Tisdale profile is interesting in showing the development of podsolic weathering on one of the heavier soil types. It has been

reported by McKibbin and Pugsley, (14), that the podsolic soils of the eastern townships of Quebec are invariably associated with light sandy to gravelly soils. Ramman (16) makes essentially the same statement in his discussion of what he terms the Northern Bleached Earths. On the other hand data reported from both Russia (5) and Alberta (26) show that podsolisation may occur even on clay soils. The analysis of the Tisdale profile substantiates this latter viewpoint, as this soil shows very clearly the effects of podsolic weathering; as mentioned in the field studies it is one of the heaviest soils found in the wooded areas of Saskatchewan and is mapped as heavy silty clay loam.

The important point in connection with this profile is that the leaching is quite pronounced in the A_2 layer, although the profile as a whole is not badly degraded. There is a relatively deep A_1 horizon, the A_2 occurring at a depth of seven inches below the surface. The B_2 layer occurs at two feet in contrast with almost four feet for the White Fox profile. The heavy texture of the Tisdale soil causes the process of degradation to proceed at a slower rate than in the case of a sandy soil. It may be assumed that the process has been in operation for a considerable period of time in view of the fact that the A_2 horizon has suffered a heavy loss of iron and aluminum. As shown by the figures almost twice the quantity of these constituents occur in the B_1 as is found in the A_2 layer. Conversely the A_2 horizon contains about twelve per cent more silica than the B_1.

The figures for moisture, loss on ignition, and phosphorus

indicate podsolic weathering also, all being higher in the B_1 than in the A_2. The figures for nitrogen are an exception, as the A_2 is the higher. This is the only profile in which such a condition was found. It may be mentioned that the nitrogen content of this profile taken as a whole is higher than was found in the other cases.

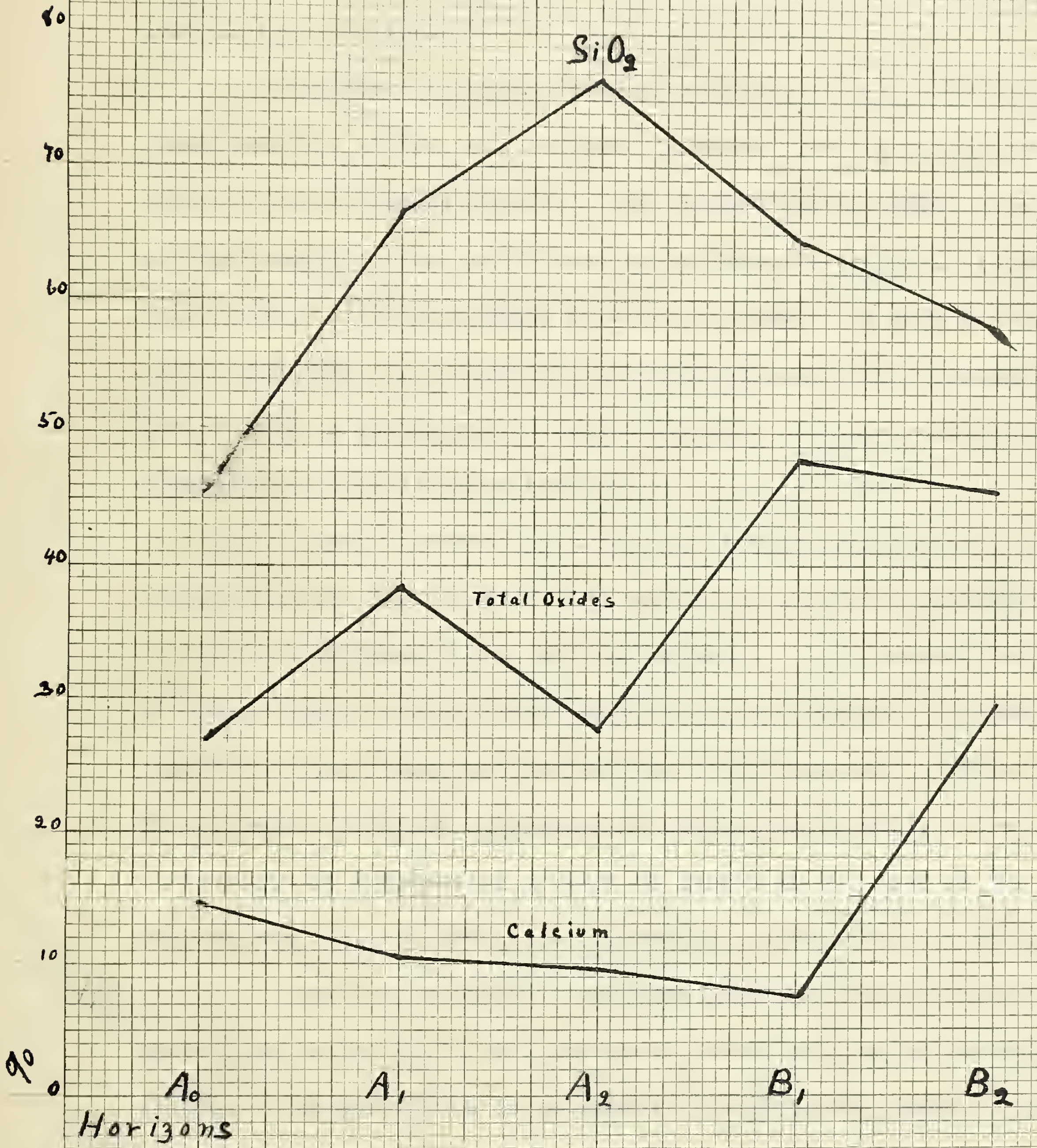
The pH values indicate that the upper layers of this profile are more acidic than those of the other soils. This is the only case where the A_0 is below a pH of 7. The content of calcium in this layer is lower than in the other A_0 horizons.

The Tisdale profile, as mentioned above, is not badly degraded; nevertheless, the intensity of podsolic weathering is quite marked. The relationship between the content of silica, total oxides and calcium in the various horizons is well brought out by means of a graphical representation of these constituents, as shown in Fig. II. (p.42)

The Crooked River profile is exceptional in that some free lime carbonate exists in the B_1 layer immediately below the A_2 horizon. Approximately .8 per cent of calcium carbonate occurs here, when the CO_2 is expressed as $CaCO_3$. It may be stated that very faint effervescence by HCl was noticed in the field in this horizon. The pH value of 7.7 and the total calcium content of 1.24 per cent are both higher than in the corresponding horizons in the other profiles. The calcium content of the B_2 is higher than that of any of the other profiles, and is only eighteen inches below the surface. This would seem to indicate that the original soil material was high in calcium. The analysis of the A_2 layer shows that podsolisation may occur even

Fig. II

Vertical Distribution of SiO_2, Total Oxides, & Calcium in a Podsolic Profile from Tisdale, (Sask.)



% SiO_2 as Shown

Total Oxides (Fe_2O_3, Al_2O_3, TiO_2.) = 2 x SiO_2 Scale.

Calcium ——— = 10 x " " .

in a highly calcareous soil, provided there is no free lime carbonate left in this horizon.

The other figures for this profile, with the exception of phosphorus and silica, all indicate leaching from the A_2 horizon and accumulation in the B_1 layers. The differences in total oxide content are much smaller than in the case of the Tisdale profile, although the difference in silica content is about the same. A part of the lower silica and total oxide content in the B horizons of the Crooked River profile may be accounted for by the dilution of these horizons by the accumulation of calcium carbonate.

It may be mentioned here that in this profile, and in the Sturgis and St. Walburg profiles, two B_1 horizons were distinguished in the field between the A_2 and B_2 horizons. The chemical analyses of these three profiles indicates that the differences in these horizons observed in the field, are indications of differences in composition. In all cases the upper B_1 horizon is slightly more acid. The differences in composition are not so marked in the case of the St. Walburg profile, but are quite noticeable in the other two soils.

The Sturgis profile indicates leaching from the A_2 and deposition in the B_1 for all the constituents determined, except silica. The phosphorus is noticeably low in the A_2 layer. The A_1 and A_2 horizons are apparently not separated properly, as indicated by the slightly higher silica content of the former. It is probable that some mixing occurred owing to the soil being very wet when sampled. The true A_1 horizon is probably very thin. The lime carbonate is

found at a depth of eighteen inches, where faint effervescence occurred in the field. The B_2 horizon has nearly five per cent of total calcium; hence this profile like that of the Crookod River soil is highly calcareous.

The St. Walburg profile is taken from the northwestern part of the province. Outside of the sandy White Fox profile, this soil shows throughout the greatest depth of leaching. The lime layer is three feet below the surface, while the calcium content of the A_2 and B_1 horizons is lower than is found in the other profiles in the same layers. The silica content of the A_2 horizon is the highest reported in these tables - almost eighty-five per cent; and there is a difference of almost eight per cent in the total oxide content of the upper B_1 as compared with the A_2. This shows greater movement of these constituents than is found in the other profiles, with the exception of the heavy Tisdale soil. The nitrogen and phosphorus content of the A_2 horizon is also the lowest found, and in the case of phosphorus is the lowest figure reported for any Saskatchewan soil to date. The moisture content and loss on ignition for this horizon are also the lowest figures recorded for the leached horizon. Another factor of importance is that of the depth of the A_1 layer; this is only .5 inches deep, and also indicates a more severe leaching process. Finally the pH values for the A_2 and B_1 horizons are all below pH 7, the upper B_1 with a pH of 6.4 being the lowest of all the samples determined.

DISCUSSION OF ANALYTICAL DESCRIPTIONS FROM OTHER SOURCES.

It may be remarked that it is difficult to obtain analytical results from other sources that can be used as a basis for comparison. Very little systematic work involving both field and laboratory methods has been attempted until the last few years. Some of the earlier work did not take into account the natural horizons of the profile and hence arbitrary depths were used in sampling. The descriptions of horizons in other cases were very brief and little knowledge of the profile is given. In other cases the constituents reported in analytical data are those of most importance from the standpoint of fertility and no results for silica and total oxides are given. Still other cases occur in which profile analysis has been carried out by acid extraction methods, whereby only acid soluble fractions of the constituents are determined. There is, of course, a considerable amount of data reported by Glinka, (5) on European soils. The above statements refer mainly to the soils of this continent.

The following tables show the composition of some podsolic soil profiles taken from other sources.

Table IV - Typical wooded (podsolic) soil of Alberta.
(Wyatt, Newton & Mather) (26)

Horizon	Depth	N.	P.	Ca	$CaCO_3$	pH.
A_0	0"-2"	.49	.09	1.18	----	6.0
A_1	2"-4"	.09	.06	.55	----	6.2
A_2	4"-19"	.03	.03	.61	----	6.2
B_1	19"-48"	.04	.03	.56	----	7.0
B_2	48"-55"	.02	.04	2.68	7.67	7.3

The above profile, compared with the degraded soils of Saskatchewan, indicates a greater degree of leaching, as shown by the lower calcium content throughout, lower zone of lime accumulation, and lower pH values. Accumulation of organic matter in B_1 is indicated by slightly higher content of nitrogen as compared to A_2 horizon. The A_2 horizon is fifteen inches in thickness - another sign of a more severely leached soil. This is about twice the thickness of the deepest A_2 of the Saskatchewan profiles. It would seem from other Alberta data that the Saskatchewan soils reported on here are more like the Alberta incipient podsolic types, which have suffered less leaching than is indicated by the above table.

Table V - Minnesota podsol soil (Baldwin) (4)

Horizon	Depth	H_2O	Loss on Ignition	N.	P_2O_5	SiO_2	Fe & Al	CaO	CO_2
A_o	3"	10.76	64.53	1.862	.31	21.6	7.55	3.24	---
A_1	1"	4.96	16.53	.44	.17	58.99	18.25	1.57	---
A_2	5"	1.25	3.64	.074	.01	73.00	16.45	1.42	---
B_1	8"	4.55	5.70	.12	.17	65.02	22.73	1.03	---
Parent material	--	----	11.20	.05	.11	53.14	20.54	7.00	7.59

The above profile is considered by Baldwin to be typical of the podsolic soils of the North Central States. It will be seen at once that the same type of weathering occurs here as in the case of the Saskatchewan soils. In the above profile the nitrogen, oxides, loss on ignition all show the effect of movement and deposition lower down. The silica is also distributed in the same way as found in our soils. The above profile shows a lime carbonate layer in what is designated as parent material. According to the depths given this is only about seventeen inches below the surface. It would seem strange if this horizon is really relatively unweathered, and, therefore, contains the lime carbonate as present in the original soil material. It would be interesting to know just how it compares with the B_2 layer of our degraded soils, particularly in view of Marbut's

classification, whereby no accumulation of lime carbonate occurs in the podsol profile.

Table VI - Soil profile of Northern Michigan (Veatch) (22).

Horizon	N	SiO_2	Fe-Al	CaO	pH
1 Humus	.47	74.69	4.30	.63	5.06
2 leached	.01	93.34	2.35	.27	4.89
3 B_1?	.06	86.64	5.24	.36	4.48
4 B_2?	.01	89.97	2.97	.28	4.82

This profile indicates a condition of rather severe leaching. There is very little nitrogen in the lower layers and a smaller calcium content than we have found in the Saskatchewan soils. This soil is much more acid also as indicated by its pH value. It is interesting to note that as in the Saskatchewan soils the lowest pH occurs in the horizon of accumulation. The ordinary horizon designations are not given in the above profile.

Table VII - Russian podsol (Glinka) (5).

Horizon	H_2O	Loss Ignition	SiO_2	Oxides (Fe., Al., Ti.)	CaO
Humus peaty A_1	3.06	12.78	66.86	15.09	1.38
Whitish A_2	1.69	5.02	74.01	15.73	.92
Brown fine grained B	4.10	6.00	63.60	21.60	.69
Granite C	.98	1.21	74.87	15.74	.63

This profile is one of Russian podsol soils reported by Glinka, which has developed from granitic parent material. It will be seen at once that the figures for water, loss on ignition and sesquioxides indicate that leaching and subsequent deposition have occurred. The content of the oxides in the B horizon is considerably higher than the parent material - thus showing an accumulation. The silica content of the A_2 also indicates a slight accumulation when the mineral is calculated on an organic matter free basis as shown by Glinka in other data. In the above profile the total oxides are higher than is usually the case in our soils. All the constituents reported indicate leaching and subsequent deposition, with the exception of calcium; this element shows a regular decrease with depth.

Another profile given by Glinka is that of a podsol on dioritic parent material. This shows the same order of leaching and accumulation characteristic of podsolic soils. The calcium, however,

is higher throughout, and over two per cent is present in the B layer. No mention is made of lime carbonate in either profile.

From the above comparative tables it is seen that these degraded soils of Saskatchewan belong to the group of podsolic soils. Their actual classification in regard to the degree of leaching exhibited by them may be a matter of doubt at the present time, but it is evident as a result of these studies that they are podsolic in nature.

AGRICULTURAL SIGNIFICANCE.

Soils which have undergone podsolic degradation are less fertile than non-podsolic soils of the same type. The lower content of nitrogen, phosphorus, calcium, and organic matter in the leached horizons is a partial explanation of the lower fertility. Another cause is the poorer physical condition of degraded soils, resulting from the deflocculation of the soil particles in the leached layers, together with the loss of many of the finer particles. As a result these soils are often rather difficult to "work" - and tend to become "baked" when dry.

The Saskatchewan soils studied in this problem are not as rich in plant food elements as the unleached soils; nevertheless, they cannot be classed as poor soils, since the leaching is not very deep, compared with the more degraded wooded soils of Alberta and elsewhere. The Tisdale soil is really very fertile, due in part to the deep A_1 layer. The other soils are considerably less productive and are all

taken from areas where very little settlement has occurred as yet.

There is no definite data available on the comparative crop yielding values of these soils, as compared with those of the park belt. In the soil survey of the Birch Hills-Melfort area, covered in the Saskatchewan Soil Survey Report No. 7, some observations were made of the agricultural value of some degraded soils. These soils occur in rolling stony areas, and the profile in general corresponds to the Crooked River and Sturgis profiles reported above. It was reported that this area was less productive than the black park soils of the Melfort plain. This was considered as being due to cost of clearing bush, low organic matter content of the soil, poor soil structure and other factors.

It may be safely asserted that most of the unsettled wooded areas of Saskatchewan are affected by the above factors. The total cost of developing these lands will be greater than was the case with the more open park and prairie soils. While it is impossible to gain full knowledge of a soil's fertility by means of a chemical analysis, such analysis does indicate the total plant food content. Since the degraded soils are poorer in necessary elements to begin with, they will undoubtedly need building up sooner than the black park soils. The following table taken from the Soil Survey Report No. 7, mentioned above, gives a comparison between a fertile park belt soil and a podsolic bush soil.

Table VIII - Comparison of Fertility of Park and Podsolic soils; as measured by supply and demand of essential elements. (Joel, Edmunds and Mitchell) (9).

Soil (surface)	Essential element	Pounds per acre	Pounds in 30 bus. crop of wheat.	No. of 30 bus. crops possible.
Melfort silty clay loam (black)	Nitrogen	15,020	57.6	261
	Phosphorus	2,150	9.6	224
Waitville loam (podsolic)	Nitrogen	2,620	57.6	44
	Phosphorus	840	9.6	87

The above figures indicate a great difference in ultimate fertility between these soils, and also indicate that nitrogen may be the more limiting element in the case of the degraded soil.

The results of some fertilizer experiments carried out on a wooded podsolic soil of Alberta are reported by Wyatt and Ward. (27) The soil used was representative of the more severely leached areas. It is stated that crops grown on this type of soil often give unsatisfactory crop yields, and in poor seasons may be entire failures. Reference was also made to the undesirable physical state of this soil type when dry.

The experiments consisted of a number of crops grown in rotation, under different fertilizer treatment. The results indicated that on such a soil lime, phosphorus and manure might be applied to good advantage, the latter being useful in improving the physical

condition of the soil. The value of a legume in the rotation was also indicated.

Further experiments on this soil are reported by Wyatt, (28) in connection with the residual effect of the fertilizer treatments. In general the conclusions arrived at were that the greatest increases in crop yield occurred during the year of application. The legume showed the greatest residual effect, and when plowed under gave a considerable increase in the yield of wheat following; phosphate and manure gave a greater residual effect than was shown by nitrogenous fertilizers.

It is reasonable to expect that the above conclusions would apply to the degraded soils of Saskatchewan, provided that these soils are degraded sufficiently to require fertilizer treatment. The type of fertilizers and the amounts and order of application can only be arrived at through experimental work, carried out over a sufficient period of time to give conclusive results. It would seem logical to obtain such information before any further great increase in settlement is made on the degraded soils.

SUMMARY

In order to obtain a better knowledge of the degraded podsolic soils found in the wooded areas of Saskatchewan, some field and laboratory studies were made of five profiles from the degraded areas.

The field studies indicated the presence of podsolic degradation, when compared with studies made of podsolic soil profiles in other parts of the world.

The soils studied included a sandy soil of presumably alluvial origin, a heavy smooth lactustrine type, and several glacial (stony) types. Despite these differences in origin the degradation process appeared to be a function of climate and vegetation rather than of parent material.

Laboratory studies consisted of the total analyses of chemical elements, moisture, loss on ignition and pH values.

The results showed that podsolic degredation had occurred in all soils, the upper layers having been leached of various elements and the lower layers having been enriched by the deposition of some of the transferred substances. The data obtained could be corelated in general with the field studies, the appearance of leaching in the profile being substantiated by subsequent analysis.

The substances leached from the upper layers included the sesquioxides of iron and aluminum, calcium, nitrogen and phosphorus. These were deposited in various amounts in the lower horizon. The movement of organic matter was indicated by the figures for nitrogen,

phosphorus and loss on ignition.

Silica in every case was present in highest amount in the leached horizons, and the total oxides were highest in the B_1 horizons.

The leaching in the ashy-grey A_2 horizon was quite severe and compared in general with results reported on podsol soils from other places. The depth of leaching was, however, much less than in the case of the podsols. The presence of lime as an accumulation is a noticeable feature; it is found in the Alberta podsolic profiles, but at greater depths as a rule. In the United States results, no accumulation of calcium carbonate is reported.

The pH values indicated that these soils are not very acidic. Higher pH values corresponded generally to higher calcium content.

The textural qualities and the content of important elements in the upper leached layers indicate that these soils are of lower fertility than the fertile black park belt soils.

Results of Alberta experiments indicate that degraded soils may respond to fertilizer treatment and to legumes when used in the rotation.

It is pointed out that the degraded soils of Saskatchewan cover most of the wooded areas that are at present unsettled, and that, therefore, a study of these soils and their agricultural significance would be a useful and eventually a necessary undertaking.

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